Persistence of diffusion-diffraction features in double-PFG experiments conducted on size distribution phantoms

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One of the most important attributes of diffusion NMR is that it can employ restricted diffusion to probe microstructures of opaque samples. The single-pulsed-field-gradient (s-PFG) methodology (Fig. 1A) employs a pair of diffusion-sensitizing PFGs that are separated by an interval in which the diffusion process takes place. When a specimen is characterized by a very narrow size distribution or by monodisperse pores, the signal decay of s-PFG experiments exhibits diffusion-diffraction minima from which important microstructural information such as the size of the pore can be derived. However, as the size distribution broadens, the diffusion-diffraction minima vanish from the signal decay, and the microstructural information can no longer be inferred.

The double-PFG (d-PFG) (Fig. 1B)) is an extension of s-PFG that has recently gained interest owing to several theoretical studies that predicted that new microstructural information can be obtained using d-PFG, even when broad size distributions are present. The theory predicts that zero-crossings of the signal (analogous to the diffusion-diffraction minima in s-PFG), should be preserved even when the size distribution is very broad.

Therefore, we conducted both s- and d-PFG experiments on size distribution phantoms, consisting of water-filled microcapillaries of various sizes.

Figure 2 shows s- and d-PFG experiments conducted on a SD phantom with $d_{av}\pm$ =14.9±4.6 μm. When s-PFG experiments (black squares) were performed, the diffusion-diffraction minima indeed vanished from the signal decay, and only minor non-monotonicities were observed, from which accurate microstructural information could not be obtained. However, the diffraction-like features were preserved in the d-PFG experiments (red circles), yielding a compartment size of 13 μm. The size is slightly smaller than d_{av} due to effects of diffusion during the gradient duration.

This new methodology may become an important tool for characterizing specimens which have broad size distributions such as porous materials, emulsions, and even axons in the central-nervous-system.
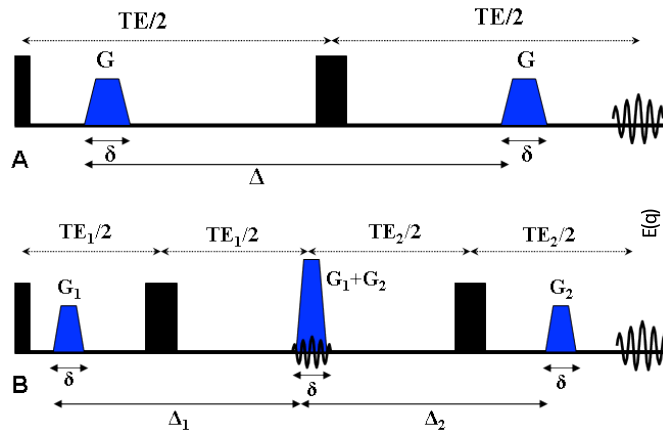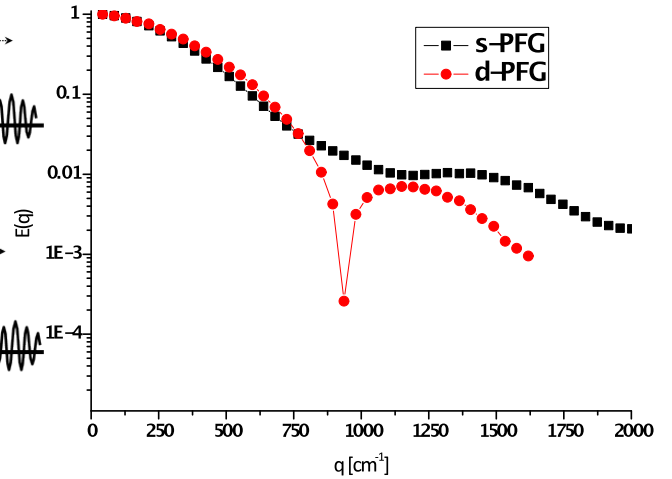

Figure 1

Figure 2